APPENDIX 22

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August 16, 2010

By Email & U.S. Mail

Robert Koroncai
U.S. Environmental Protection Agency
1650 Arch Street
Philadelphia, PA 19103

Re: James River Site-Specific Chlorophyll-*a* Criteria

Dear Mr. Koroncai:

Following up on our conversation at the recent EPA Region III Municipal Water Quality Meeting in Washington, D.C., I am writing to provide the attached summary of VAMWA's perspectives and recommendations on the James River Site-Specific Numeric Chlorophyll-*a* Criteria and associated wasteload allocations.

A core recommendation is that the Chesapeake Bay and/or James River TMDL process accommodate a review and appropriate revision of these unique criteria to improve the currently weak linkage between the criteria and designated use attainment. As you know, aside from the higher D.C. criteria, the Virginia/James River criteria are the only numeric chlorophyll-a criteria for Bay tidal waters, and these were adopted essentially on a first-ever or experimental basis in 2005 despite significant remaining scientific questions. Furthermore, significant new information is available at this time that is not reflected in the existing criteria.

The attached information, which was prepared by VAMWA's technical team, demonstrates the requested review and update is both a practical and necessary step prior to TMDL-based additional regulation beyond the Tributary Strategy level.

Sincerely,

Chris Pomeroy

Christopher D. Pomeroy
General Counsel

Enclosure

Copy to:
Mr. Alan Pollock, DEQ
VAMWA Board

CHLOROPHYLL-A STANDARDS & IMPLEMENTATION
AUGUST 16, 2010

VAMWA has been active on the chlorophyll-*a* topic since USEPA's initial efforts to derive Baywide criteria in 2000. Over this time, VAMWA representatives have served on technical committees, contributed independent data analyses, and provided numerous sets of technical comments on chlorophyll-*a*. In the interest of being concise, the main body of this letter summarizes and references much of this previous work. The summary is organized into the following categories:

I. A brief history of the James River chlorophyll-*a* criteria
II. Opportunities to improve the chlorophyll-*a* criteria
III. Perspectives on the current TMDL process and draft wasteload allocations
IV. Summary of recommendations

I. A BRIEF HISTORY OF THE JAMES RIVER CHLOROPHYLL-*A* CRITERIA

The technical work underlying the existing James River chlorophyll-*a* standards dates to various USEPA and DEQ efforts in the 2000-2005 timeframe. Following is a summary of these efforts, which is included to provide the necessary perspective on the situation Virginia faces today.

A. 2000-2003—USEPA-Led Efforts

Upon the adoption of the Chesapeake 2000 agreement June 2000, USEPA announced its intention to refine or derive Baywide criteria for dissolved oxygen (DO), water clarity, and chlorophyll-*a*, and formed scientific task groups for each criterion. Representatives from VAMWA served on all three task groups. The subsequent technical work over 2000-2003 revealed that, while all three criteria were technically challenging, the chlorophyll-*a* criterion was by far the most difficult to relate to designated use attainment in a manner that was not simply redundant of DO and water clarity criteria.

The first draft of the document (July 2001) emphasized the "Phytoplankton Reference Community Approach" along with other secondary sources of information such as historical values, literature values, and contributions to light attenuation and low DO. After the first review period, it was recognized that these lines of evidence lacked sufficient linkages between chlorophyll-*a* and designated uses (VAMWA & MAMWA, 2001).

A second draft (May 2002) emphasized "food quality" connections and mesoplankton abundance. VAMWA supported exploration of this approach, and contributed independent data analyses. However, rigorous reviews of this approach revealed that chlorophyll-*a* was not a useful indicator of adverse impacts to food quality or mesoplankton abundance (VAMWA & MAMWA, 2002). The draft criteria document received an adverse review by the Scientific and Technical Advisory Committee (STAC, 2002), and the "food quality" discussion was removed as a primary line of evidence. Similarly, linkages of chlorophyll-*a* to harmful algal blooms (HABs) were attempted, but there was insufficient data/information at that time to derive widely-applicable criteria (VAMWA & MAMWA, 2003).

Ultimately, USEPA recognized these deficiencies and made the correct decision not to publish Baywide chlorophyll-*a* criteria as part of the 2003 criteria document (USEPA, 2003). What *was* published represented a compilation of the multiple lines of inquiry from the 2000-2002 timeframe, a related table with a wide range of chlorophyll-*a* values, and an encouragement for states to use this information in developing site-specific chlorophyll-*a* where needed. In our review of this document (VAMWA & MAMWA, 2003), VAMWA expressed concern that the technical problems of using these values as criteria might not be fully recognized by the document's intended audience, and recommended specific language to prevent this outcome.

B. 2003-2005—Derivation of James River Chlorophyll-a Criteria

Due to the James River's relatively healthy DO levels, lack of significant influence on mainstem Bay DO, and solids-dominated clarity issues, it was recognized that neither DO nor water clarity criteria were likely to justify stringent nutrient controls in the James River estuary. In 2003, the Virginia DEQ initiated a rulemaking to make chlorophyll-*a* criteria the primary driver of nutrient controls in the James River.

In attempting to derive James River chlorophyll-*a* criteria in 2003-2004, the Virginia DEQ relied on the limited information available at the time. The technical basis for the criteria published in November 2004 relied on heavily on lines of support drawn from the USEPA's 2003 criteria document. The technical support document (Virginia DEQ, 2004) emphasized concerns over high chlorophyll-*a* and cyanophyte levels in the tidal fresh segments, and trends in potential bloom-forming phytoplankton taxa in the lower estuary. The proposed chlorophyll-*a* values represented a professional judgment of seasonal mean conditions representing a balanced phytoplankton population, and were also influenced by expectations of attainability under expected nutrient control scenarios.

VAMWA was highly involved at all stages of the public participation process for the James River chlorophyll-*a* criteria. Due to our familiarity with the scientific shortcomings of the 2001-2003 efforts, we initially recommended that Virginia adopt an adaptive management approach that used monitoring and research to strengthen the understanding of relations between chlorophyll-*a* and harmful algal blooms (VAMWA, 2004). When this course was not followed, we commented extensively on the subsequent criteria proposals (VAMWA 2005a, 2005b). In general, we concluded that the proposed criteria were highly subjective, lacked scientific linkages to unfavorable algal/ecological conditions, were strongly influenced by a pre-determined load allocations, and could result in huge expenditures with few tangible benefits. Our comments were supported by independent literature reviews and data analysis.

In 2005, the Virginia DEQ (with USEPA's assistance) performed the *James River Alternatives Analysis* (DEQ, 2005) in response to stakeholder concerns over the subjectivity, cost, and attainability of the proposed criteria. The purpose of this modeling analysis was to determine if "different cap load allocations could achieve equivalent environmental benefits with much lower economic impacts". The results were used not only to adjust the cap allocations, but also to adjust the proposed chlorophyll-*a* criteria in certain segment seasons. Hence, the criteria adopted in 2005 were inherently linked to expectations of attainment under a specific management scenario and the Phase 4.3 modeling framework.

C. 2008-2010—New Model, Different Answer

Under the present Phase 5 modeling framework used for the 2010 TMDL, the James River chlorophyll-*a* criteria are no longer predicted to be attainable at the previously-established loading level. This has put Virginia in the situation of possibly incurring an *additional* $1.5 to 2.0 billion in nutrient implementation costs to meet a scientifically problematic, first-of-its-kind standard that was itself partially based on the assurance of attainability under a different modeling framework.

Section III of this letter summarizes VAWMA's serious concerns with the 2008-2010 TMDL allocation process for the James River. However, we would first like to take the opportunity (in section II) to explain why we believe that the James River chlorophyll-*a* standards can be markedly improved from a scientific and ecological basis, relying on data and research not available in 2000-2005.

II. OPPORTUNITIES TO IMPROVE THE CHLOROPHYLL-*A* STANDARD & MODELING FRAMEWORK

In VAMWA's view, several important new sources of information and data provide the opportunity to reevaluate and improve the basis of nutrient controls in the James River basin. These include academic research, USEPA research, and DATAFLOW monitoring results for the both the upper and lower James River. It would be premature to proscribe the specific methods or results of such as reevaluation. However, in the interest of showing the real promise of such an effort, we present here some specific examples of how linkages could be improved.

In VAMWA's view, modest year-to-year variations in the seasonal mean chlorophyll-*a* probably have very little to with aquatic life use attainment. One potential basis for improved an improved nutrient control framework would be linkages between chlorophyll-*a*, harmful algal blooms (HABs), and/or HAB toxins. Potential HAB taxa occur in both the low salinity and high salinity segments of the James River estuary. Although research available in 2003-2005 began to make some of these linkages, we believe that data and research since 2005 provide the opportunity to greatly improve the James River chlorophyll-*a* criteria.

A. Low Salinity Segments

In the 2004-2005 timeframe, VAMWA advocated the exploration of chlorophyll-*a* criteria in low salinity segments based on segment-specific empirical relations with potential HAB taxa such as *Microcystis aeruginosa*, which is a common inhabitant of the tidal freshwater James River. Certain strains of *M. aeruginosa* produce a toxin called microcystin that can be harmful to humans and aquatic life (Lampert, 1981; Fulton and Paerl, 1987; Fulton and Paerl, 1988), and *M. aeruginosa* has been known to cause nuisance blooms in other systems such as the Potomac River. It is not known if the James River strains are toxin-producing, and in general the James River does not experience the types of nuisance bloom conditions that have sometimes occurred on the Potomac River. However, previous work by VAMWA has explored the relations between chlorophyll-*a*, total cyanophytes, *M. aeruginosa*, and mesozooplankton abundance. Relatively strong empirical relations were evident.

Two years after the adoption of the James River chlorophyll-a criteria the USEPA published the *2007 Chlorophyll Criteria Addendum* (USEPA, 2007). This document provided the basis for chlorophyll-*a* criteria based on linkages with *M. aeruginosa*. VAMWA considered portions of this document as a step forward in linking chlorophyll-*a* criteria to designated use attainment. A strength of USEPA's approach was the joint consideration of the chlorophyll-*a*, *M. aeruginosa* cell count, and microcystin concentration.

We believe this approach merits consideration for application to the tidal freshwater James River. Relations between chlorophyll-*a* and *M. aeruginosa* can vary widely between segments, and so it would recommended to closely explore the James-specific relations. The *2007 Chlorophyll Criteria Addendum* relied heavily on data from the Potomac River and upper Chesapeake Bay tributaries, and derived a threshold chlorophyll-*a* concentration of 27.5 ug/L. In contrast, the appropriate threshold for the James River is probably in the 36-40 ug/L range (Figure 1). It is also recommended to conduct monitoring to determine whether the James River strains of *M. aeruginosa* produce microcystin, and if so, at what concentrations.

It is not known if a HAB-based criterion for the low salinity segments of the James River would be more or less stringent than the existing criteria. The criteria magnitude would likely rise, but changes in the frequency/duration components could cause the criterion to become more stringent. In addition, it must be considered that cyanophytes such as *M. aeruginosa* are natural components of the phytoplankton assemblage in this segment, and thus attainability should also factor in to the overall assessment. Attainability is especially important to consider for the region near the confluence of the James River with the Appomattox River, where river morphology and hydraulics cause a natural chlorophyll-*a* peak. Nevertheless, VAMWA strongly recommends consideration of the HAB-related lines of evidence, among other potential approaches for refining the James River nutrient control framework.

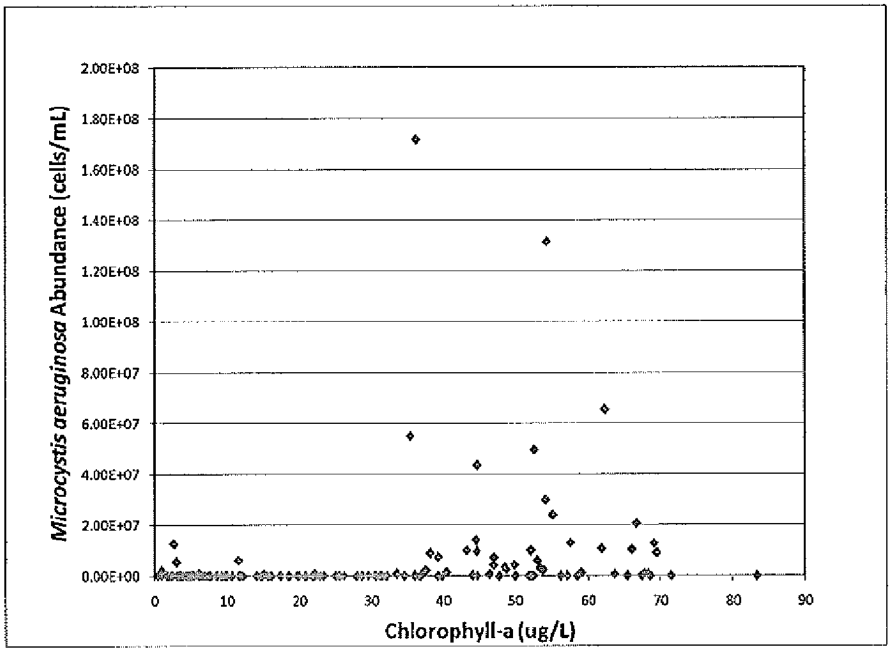

Figure 1—Scatterplot of *M. aeruginosa* abundance versus chlorophyll-a at station TF5.5 in the James River estuary, 1986—2006. Data courtesy of R. Lacouture.

B. Higher Salinity Segments (Lower James River)

As in the upper estuary, HAB linkages merit exploration as one potential basis for revision of the nutrient control framework in the lower James River estuary. During the final comment period on the standards, VAMWA recommended an anti-degradation and adaptive management approach be taken on the lower James River as a precaution against HABs. This recommendation reflected our belief that the HAB related end-point probably offered the best approach to developing a defensible standard among the many others that were considered. Addressing HABs is important because they can result in direct effects on designated uses such as fish, oysters, user perceptions, etc.

There is now considerably more data and information available to make connection between chlorophyll-*a* and HABs than was previously available. HRSD began weekly water quality monitoring in the lower James River in 2005 that is presently on-going. The main objective of the program is to collect data sufficient to assess the chlorophyll and water clarity standards according the EPA guidance (EPA 2003) for monitoring bay related standards. HRSD, VADEQ, and VIMS collectively established procedures to ensure quality control and incorporate the data in the regulatory assessments of the standards. The monitoring program utilizes the DATAFLOW system developed by VIMS for the purposes of chlorophyll *a* and water clarity criteria assessment (Moore and others 2003). Since its inception there have been over 350 cruise dates successfully conducted in the Hampton Roads. As a result, over 1.2 million chlorophyll-*a* and related water quality observations are available. This information along with continuous monitoring site data collected by VIMS is made publically available through the Virginia Estuarine and Coastal Observing System (VECOS) (http://www2.vims.edu/vecos/). This information would be valuable to a standards revision because it serves to assess the dynamics of algal blooms with a high level of spatial and temporal resolution.

During 2008 Old Dominion University (ODU) began using VECOS data to expand its research into the environmental triggers and dynamics of HABs in the Hampton Roads. The products of this research resulted in a number of scientific papers related to *Cochlodinium polykrikoides* blooms (Mulholland and others, 2009; Morse and others, 2009; and Morse and others, 2010) These studies indicated that *Cochlodinium polykrikoides* blooms in 2007 and 2008 coincided with periods of intense summer rains and storm water runoff following droughts. Initiation of algal blooms was also found to be correlated with neap tides, vertical stratification of the water column, and low wind conditions. Similar patterns have been observed in 2009 and 2010 since the scientific papers were written. Another major finding was that the Lafayette and Elizabeth Rivers appear to act as an initiation grounds for *Cochlodinium polykrikoides* blooms. Through use of the VIMS model the authors demonstrated that that the bloom organism was transported from the Lafayette and Elizabeth Rivers into the lower James River where it later became fully established.

The above research results are directly applicable to chlorophyll management of the James River. We believe that key elements to reducing chlorophyll a levels in the James River in the future should include (a) greater measures to reduce nutrient pulses due to storm water inputs and (b) placing more attention to the inter-connected nature of the Lafayette and Elizabeth River systems with respect to James. The present TMDL and associated modeling does not capture these key elements and smaller scale effects.

Based on the greater information now available. the following specific concepts should be considered among other opportunities for revision of the nutrient control framework for the lower James River.

1. <u>Nutrient control framework revision</u>

- Revise the standard to address *Cochlodinium polykrikoides* blooms as the indicator HAB. Although other HAB phytoplankton species are also of concern (particularly toxin formers), *Cochlodinium polykrikoides* appears to be the best studied, obvious, and problematic for Hampton Roads. Annual summer blooms of this species have become a predictable and routine occurrence. Blooms of this species are primarily responsible for the non-attainment status of the existing chlorophyll standard during the summer. Because of the extreme influence of bloom events on ambient chlorophyll*a* conditions it is essential that the standard and modeling system be revised to effectively address them. <u>Note</u>: *Heterocapsa triquetra* appears to be responsible for algal blooms in the JMSMH segment during the spring season and should be considered during a standards revision as well for the spring season. However, the data related to this species is presently more limited.

- Refine relationships between algal cell counts and impacts on designated uses. Some data is presently available in the literature but additional studies are needed to determine cause and effect relationships between cell counts and various biological end-points for the specific area.

- Refine relationships between algal cell counts and chlorophyll-*a*. Recent data (Figure 2) indicates a regression relationship exists between *Cochlodinium polykrikoides* cell counts and chlorophyll a. A continued refinement of this relationship could provide a direct connection between chlorophyll a concentration and impairment of designated uses (i.e. through the relationship with cell counts).

- Determine acceptable limits on the size and duration of algal blooms. Isolated bloom patches and/or those which are short-lived may not cause significant ecological damage in a large system such as the James. However, when these blooms become expansive and/or long-lived the environmental consequences can be more serious. Part of the proposed standard revision should consider establishing appropriate limits at these scales. Once established these limits could become the basis for biological reference curves needed for criteria assessment. The existing chlorophyll standards utilize a default 10% reference curve that is unrelated to designated use impairment.

2. Chlorophyll-*a* modeling improvements

Our recent comments on the chlorophyll-*a* modeling indicated concerns about the reliability of the results relative to the precision with which they were expressed. To address those concerns we recommend that the chlorophyll-*a* modeling be significantly improved. It is essential that the TMDL model reasonably simulate bloom dynamics and the controlling processes at scales upon which they occur. However, the existing model was designed to simulate long term averages in chlorophyll and estimate the effects of nutrient reduction on chlorophyll-*a* as step trends. Such a simplistic modeling approach cannot assess the effects of nutrient reduction on short-term bloom events, which represent the true environmental problem -- and the present cause for standards non-attainment. As a result, we have very little confidence that the James River will actually respond to nutrient reduction in the manner in which it is now projected. High density chlorophyll-*a* data that is now available in the lower James River would greatly assist in the development and calibration of models relative to such bloom events.

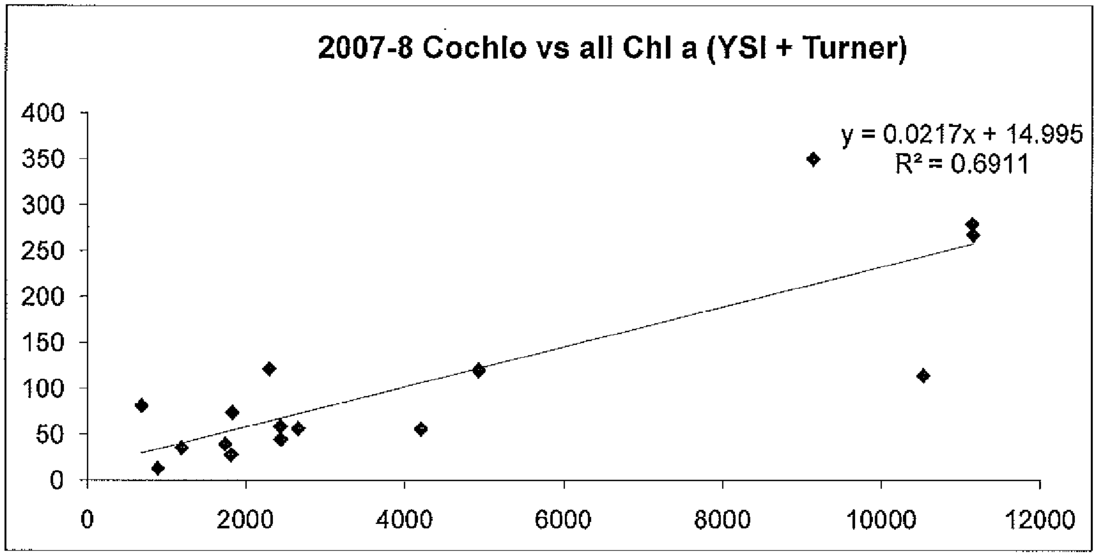

Figure 2—Relationship between Cochlodinium cell counts (x-axis- #/ml) vs chlorophyll a (ug/l). Figure and data provided courtesy of Ryan Morse, Old Dominion University.

In addition, we support EPA's efforts to consider the role of Atlantic menhaden in relation to management of chlorophyll-*a*. Recent modeling work has shown that their migration into the tributaries and associated consumption of algae has the potential to affect chlorophyll-*a* and associated compliance with the standards. Although present menhaden stocks do not appear to dramatically reduce chlorophyll-*a* (as long term averages) incremental effects due to increasing the size of the stock are considered comparable to nutrient reduction. We recommend that additional analyses be conducted to evaluate the effect of increasing menhaden stocks on seasonal peaks and/or worst years in the record. Further, additional modeling enhancements should be made such that the menhaden migration and residence time varies according to a food gradient. A number of papers indicate that menhaden consumption of algae increases in areas with higher chlorophyll-*a*. This is logical since the species would remain longer in an area with greater availability of food. Because the model does not presently capture these foraging effects the available reductions in chlorophyll due to menhaden (especially during bloom conditions) could be under-estimated.

In summary, effective management of the nutrient control framework in the lower James River requires a revision of both the standard and modeling framework.

III. Perspectives on the Current TMDL Process and Draft Wasteload Allocations

The outcome of the 2008-2010 TMDL process resulted in large (15-30%) reductions in the James River basin's nutrient allocations, estimated to cost an additional $1.5 to 2.0 billion in capital implementation costs above the already-costly tributary strategy level of effort (VAMWA, 2010a). In VAMWA's view, these large cuts and increased expenditures are unjustified both on technical and policy grounds. Major problems include: (1) the failure to resolve problems with the James River chlorophyll-*a* criteria; (2) a problematic, non-transparent modeling framework; and (3) lack of water quality benefits. These problems were discussed in a prior technical memo (VAMWA 2010b—Attachment A) and summarized below.

A. Failure to Resolve Problems with James River Chlorophyll-*a* Criteria

As outlined in section I of this letter, the James River chlorophyll-*a* criteria represented a difficult, highly subjective, first-of-its kind regulation. Linkages to ecology are weak at best, and the criterion was directly based (in part) on model predictions of attainability. It is unacceptable that criteria and allocations should be based on one model prediction, and then huge allocation cuts promoted based on another modeling framework, without revisiting the criterion itself. Such an approach would ignore the history and uncertain nature of the standard. More importantly, it would fail to take advantage of the opportunity to improve the scientific/ecological basis of the standard.

B. Problematic, Non-Transparent Modeling Framework

Since December 2009, VAMWA has raised questions on the James River chlorophyll-*a* modeling calibration and utility (Bell, elec. comm., 4 Jan. 2010). These include

- Obviously erroneous calibration in certain segment-seasons (JMSTFL, JMSPH).
- Model post-processing problems as evidenced by problematic regressions used to scenario-transform the data.
- Unexplained model anomalies
- High leverage of few data in the data transformation process (e.g., September 1999 data at LE5.2).

Although these issues have been recognized for certain segment-seasons in which there were most obvious, we see no indication that the CBP has performed a more systematic review of the same issues in all segment-seasons, determined the causes/extent of model anomalies, or fully evaluated the predictive capabilities of the model. We see no evidence that USEPA has performed a systematic examination of whether the model correctly predicts the magnitude and direction of inter-annual changes in chlorophyll-*a,* nor an examination of whether the same problems that cause counterintuitive results in some segment-seasons might also be more causing more systematic, less obvious problems in other segment-seasons.

Under the current approach, management decisions are highly susceptible to the criticism that CBP has been highly selective and partially arbitrary regarding which model predictions are usable and which are not. We have recommended that the CBP develop a set of objective criteria for evaluating model behavior that includes: (1) a systematic evaluation of the ability of the model to quantify changes in chlorophyll-*a*; and (2) an evaluation of the causes of problem model chlorophyll-*a* predictions, and how those causes might affect the model accuracy/precision on a model global level (VAMWA, 2010b—Attachment A)

B. Lack of Water Quality Benefits

USEPA justification for going beyond the 190/13 allocation level appears to be 2-3% reductions in non-attainment in selected segment seasons, corresponding to 1-2 ug/L reduction in chlorophyll-*a* in selected segment seasons (VAMWA, 2010b—Attachment A). It is a misapplication of the model framework to claim that it is capable of distinguishing between model scenarios at these levels, or that huge implementation/cost escalations should be made based on these tiny predicted shifts.

If the model cannot distinguish between D.O. non-attainment rates of 0% and 1% (as acknowledged by USEPA), the spread in distinguishable non-attainment rates for chlorophyll-*a* can be expected to be greater. VAMWA has performed analyses to demonstrate that the tiny predicted shifts in chlorophyll-*a* are smaller than the field/laboratory error and smaller than could be detected in long-term monitoring data (VAMWA, 2010b—Attachment A). The post-processing regression equations for the key scenarios in question might not even be significantly different. Although VAMWA does not have yet access to the regression data, is appears likely that statistical hypothesis testing would indicate that the parameters of these regressions might not even be statistically distinguishable. Given the strong implicit margin of safety of the Bay TMDL, VAMWA believes it is acceptable to base allocations on "essentially equivalent" model scenarios, with the choice of scenario informed by a strong understanding of the precision of the underlying criteria, model predictions, monitoring capabilities, and cost-benefits.

IV. SUMMARY OF RECOMMENDATIONS

Based on the technical comments and perspectives present in this letter, VAMWA's recommendations are as follows:

A. Set the James River basin's 2010 TMDL allocations at tributary strategy levels.

B. In the TMDL/WIP process, include opportunity for a comprehensive reevaluation of the James River chlorophyll-*a* criteria and modeling framework, to be completed by 2017. This time period also provides an excellent opportunity to assess the influence of tributary strategy implementation progress on the dynamics of existing algal blooms on the James River. A number of point source projects are scheduled to be completed by January 2011. Continued application of the DATAFLOW program over time offers a means to assess and quantify changes in HABs and chlorophyll levels relative to implemented nutrient controls during this time period.

C. Review the James River TMDL allocations in 2017 based on the outcome of the criteria review.

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ATTACHMENT A

June 30, 2010 Review of USEPA James River Chlorophyll-*a* Recommendations and Supporting Materials.

MALCOLM PIRNIE

Technical Memorandum

Date:	June 30, 2010
To:	Virginia Association of Municipal Wastewater Agencies
From:	Clifton F. Bell, Malcolm Pirnie, Inc. Will Hunley, Hampton Roads Sanitation District
Re:	Review of USEPA James River Chlorophyll-*a* Recommendations and Supporting Materials

The following technical comments are related to materials contained in the USEPA Chesapeake Bay Program's (CBP) presentation entitled "Achieving Attainment of the James Chlorophyll Water Quality Standard", dated June 18, 2010. In this presentation, EPA concludes that nutrient loadings of 23.5 TN/2.34 TP were estimated to achieve the James River chlorophyll-*a* standards. If these specified loadings were chosen as basin allocations they would result in a reduction of 4.6 TN/1.31 TP relative to the presently established tributary strategy loads of 28.1 TN/3.65 TP. However, the available technical information does not adequately support or justify nutrient reductions beyond the existing tributary strategy level for the following reasons:

- The James River chlorophyll-*a* modeling framework continues to have major technical problems including poor calibration and unexplained anomalies.
- The CBP has only partially recognized/addressed modeling problems, and has lacked clear criteria for evaluating the model accuracy, precision, and utility. The result has been a semi-arbitrary selection of which model results/data to use for load allocation or which model results to ignore.
- The predicted changes in chlorophyll-*a* (on the order of 1-2 ug/l seasonal average and 2-4% in terms of non-attainment rates) are smaller than those than can be precisely distinguished by the model, detected in monitoring data, or concluded to have ecological significance.
- Relatedly, the predicted response of chlorophyll-*a* to nutrient load reductions are extremely "flat" in key segment-seasons. Such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

Specific comments are provided below:

1. *The James River chlorophyll-a modeling framework has major calibration/behavior problems that have only been partially recognized and addressed*: Since December 2009, VAMWA has raised questions on the James River chlorophyll-*a* modeling calibration and utility (Bell, elec. comm., 4 Jan. 2010). Although the CBP has not specifically responded to the VAMWA's request for a detailed examination of model calibration

problem, a review of the June 18, 2010 materials indicates that the CBP has recognized certain model calibration and post-processing issues, including the following:

- Obviously erroneous calibration in certain segment-seasons (JMSTFL, JMSPH).
- Model post-processing problems as evidenced by problematic regressions used to scenario-transform the data.
- Unexplained model anomalies
- High leverage of few data in the data transformation process (e.g., September 1999 data at LE5.2).

Although these issues have been recognized for certain segment-seasons in which there were most obvious, we see no indication that the CBP has performed a more systematic review of the same issues in all segment-seasons, determined the causes/extent of model anomalies, or fully evaluated the predictive capabilities of the model. The main criteria that CBP appears to have used to deem model results as acceptable for a given segment-season appear to be:

- Whether or not the model predicts the approximate range of chlorophyll-*a*, without a systematic examination of whether the model correctly predicts the magnitude and direction of interannual *changes* in chlorophyll-*a*.
- Whether or not the model predicts decreasing chlorophyll-*a* with decreasing nutrient loads, without an examination of whether the same problems that cause counterintuitive results in some segment-seasons might also be more causing more systematic, less obvious problems in other segment-seasons.

Under the current approach, management decisions are highly susceptible to the criticism that CBP has been highly selective and partially arbitrary regarding which model predictions are usable and which are not. It would be recommended that the CBP develop a set of objective criteria for evaluating model behavior that includes: (1) a systematic evaluation of the ability of the model to quantify changes in chlorophyll-*a*; and (2) an evaluation of the causes of problem model chlorophyll-*a* predictions, and how those causes might affect the model accuracy/precision on a model global level.

2. *The predicted changes in chlorophyll-*a *are smaller than can be precisely quantified by the model*. Based on a review of the June 18, 2010 materials, CBP's justification for going beyond the 190/13 allocation level appears to be very small decreases in chlorophyll-*a* and non-attainment rates:

- 2-3% reductions in non-attainment in selected segment seasons (JMSTFL, JMSMH)
- 1-2 ug/L reduction in chlorophyll-*a* in selected segment seasons. (see Attachment A)

It is a misapplication of the model framework to claim that it is capable of distinguishing between model scenarios at these levels, or that major management decisions should be made based on these tiny predicted shifts. The precision of chlorophyll-*a* predictions can be expected to be significantly less than that for mainstem Bay dissolved oxygen (D.O.), which enjoys a much better calibration. If the model cannot distinguish between D.O. non-attainment rates of 0% and 1% (as acknowledged by CBP), the spread in distinguishable non-attainment rates for chlorophyll-*a* can be expected to be greater. Given the strong implicit margin of safety of the Bay TMDL, it cannot be concluded that model is precise enough to distinguish between scenarios that predict 0-1% nonattainment and 2-4% nonattainment.

The post-processing regression equations for the key scenarios in question might not even be significantly different. Examining the chart on the lower right of slide 12, is appears that the offset in regression equations for multiple scenarios is significantly less than the spread of data around the regression lines. (It is recommended to zoom in on the slide to visually examine the three scenario lines between the calibration and E3 scenarios). Although VAMWA did not have access to the regression data, is appears likely that statistical hypothesis testing would indicate that the parameters of these regressions are within each other's 95% confidence limits, and they are probably not even statistically distinguishable.

3. *The predicted changes in chlorophyll-*a *are smaller than could be detected in monitoring data*. It can demonstrated that tiny predicted shifts in chlorophyll-a between the 190 scenario and the "between 170/Potomac" scenario would not even be detectable in light of environmental, sampling, and analytical variability. For example:

(a) Power analysis demonstrates that even after long (25 year) monitoring periods, the minimum significant difference (MSD) in seasonal mean chlorophyll-a would be in the 2-4 ug/L range for most attaining segment seasons (Attachment B). Thus, it appears that the modeled shift in chlorophyll-*a* between the 190 and the "between 170/Potomac" scenario would probably not be detectable in the monitoring data.

(b) Based on a review of laboratory split sample results for the 1991-2000 James River data obtained from the CBMP data hub, the median relative percent difference (RPD) in chlorophyll-*a* samples was about 16 percent, corresponding to 1-4 ug/L chlorophyll-*a*, depending on segment and season (Attachment C). Thus, analytical variability alone is equal to or greater than the modeled shifts in chlorophyll-*a* between the 190 scenario and the "between 170/Potomac" scenario. Consideration of field (sampling) variability would the total variance of chlorophyll-*a* measurements to increase even further.

4. *The predicted changes in chlorophyll-*a *are not ecologically significant*. The difference in chlorophyll-*a* levels predicted between tributary strategy and the proposed reduced allocation scenarios (on the order of 1-2 ug/l seasonal average and 2-4% in terms of non-attainment rates) are exceptionally small in magnitude. This estimated level of change is too small to be seriously considered a matter of practical importance or consequence to Bay restoration. Even if the model could adequately discern such differences (which we dispute as discussed above) they would probably not result in tangible environmental

benefits. It should be remembered that the chlorophyll-*a* standard development process was acknowledged by VDEQ and stakeholders to be highly imprecise. Although its precision could not be quantified, revisions made to the criteria values on the basis of attainability were well within the differences described above. This shows that environmental conditions are essentially equivalent at the scale of a few micrograms.

VAMWA has consistently recommended that the James River chlorophyll-*a* standards eventually undergo reevaluation to take advantage of more recent monitoring data and research. It would be inappropriate to slash load allocations unless such a process clear demonstrated the ecological need.

5. *The predicted response of chlorophyll-a to nutrient load reductions are extremely "flat" in key segment-seasons*. This means that very large reductions in nutrient loading would result in only very small incremental reductions in chlorophyll-*a* concentrations and/or reductions in non-attainment rate. For example the critical segments of the tidal freshwater and lower estuary are predicted to have response rates of approximately 0.4 and 0.2 ug/l chlorophyll response per Mlb/yr TN reduction. Such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

In previous Bay TMDL comments HRSD estimated nutrient control capital costs at $150M per mpy TN reduction. Clearly, such a misapplication of the modeling framework could lead to huge expenditures without significant changes in standards attainment or result in tangible environmental improvement.

CONCLUSIONS

Although we recognize the tight schedule for the Baywide TMDL, we do not believe it is the best interests of Virginia or the environment to make large cuts to allocations on the basis of near non-detectable shifts in chlorophyll-*a* predicted by a problematic, imprecise model. It is recommended that TMDL allocations for the James River be based on the 191/14.4 (Tributary Strategy) scenario, and that Virginia initiate a longer-term process for reevaluating and refining the modeling framework, chlorophyll-*a* standards, and load allocations as necessary.

ATTACHMENT A
Estimation of the Magnitude of Model-Predicted Changes in Chlorophyll-*a*

This attachment describes how the CBP presentation entitled "Achieving Attainment of the James Chlorophyll Water Quality Standard" (dated June 18, 2010) was used to interpret the magnitude of predicted changes in seasonal average chlorophyll-*a* between the 190/12.7 scenario and the "between 170/Potomac" scenario. VAMWA did not have access direct access to model output or post-processing regression equations for most segments and months. Therefore, the approximate magnitude of the shift was estimated by examination of regression relationships for key segment-months:

- JMSTFL April 1995 (slide 6), taken as representative of JMSTF Spring
- JMSMH September 1999 (slide 12), taken as representative of JMSTF Summer

The offsets in predicted ln_chla between regression lines for different scenarios were quantified as a function of decreases in the James River total nitrogen load. These demonstrated an approximately linear relation between ln_chla and TN load, with the following approximate slopes:

- JMSTFL Spring: 5.72E-2 reduction in ln_chla for every 1 Mlb/yr TN reduction in the James River TN load.
- JMSMH Summer: 3.37E-2 reduction in ln_chla for every 1 Mlb/yr TN reduction in the James River TN load

The "between 170/Potomac" scenario represents a 3.1 Mlb/yr reduction in James River TN load, relative to the 190 scenario. This corresponds to the following predicted reductions in ln_chla:

- JMSTFL Spring: 0.177 reduction in ln_chla.
- JMSMH Summer: 0.104 reduction in ln_chla

As these JMSTF-Spring and JMSMH-Summer approach attainment with the existing chlorophyll-*a* criteria, their seasonal average chlorophyll-a values will approach 15 ug/L and 10 ug/L, respectively. At these levels, the predicted reduction in ln-chla listed above would correspond to the following reductions in chlorophyll-a concentration:

- JMSTFL Spring: ~2 ug/L reduction in chlorophyll-*a*
- JMSMH Summer: ~1 ug/L reduction in chlorophyll-*a*

ATTACHMENT B
Power Analysis of Seasonal Mean Chlorophyll-*a*

A two-sample power analysis was conducted to determine the minimum significant difference (MSD) in the seasonal mean chlorophyll-*a* concentrations that could be expected in the James River, Virginia. Values of α and β were set to conventional values of 0.05 and 0.2, respectively. The value of n was selected as 25, representing the approximate number of years for which a pre-TMDL seasonal mean could be calculated for most James River segments, and also representing a 25-year post-TMDL monitoring period.

In order to determine the standard deviation of the chlorophyll-a seasonal means, 1991-2000 monitoring data were obtained from the CBMP data hub. Seasonal means were calculated simple as the mean of all surface layer chlorophyll-*a* values by segment and season (spring & summer). These seasonal mean values were compared to water quality criteria. Standard deviations were calculated for segment-seasons for which the seasonal mean values were below the criteria (Table A.1). This represents a simplification of the full CFD-based assessment process, but was conducted to identify the approximate standard deviations of seasonal mean chlorophyll-a values in segment-seasons that are likely to be in attainment.

TABLE A.1—Standard Deviation of Seasonal Mean Chlorophyll-*a*, 1991-2000

Season	JMSMH	JMSOH	JMSPH	JMSTF1	JMSTF2
Spring	2.8	4.5	2.4	4.1	2.1
Summer	2.3	3.7	1.9	4.2	3.9

The power analysis was conducted using the software of Lenth (2010). Result (Table A.2) indicate that the MSD in seasonal mean chlorophyll-*a* is 2-4 ug/L for most attainment segment-seasons.

TABLE A.2—Minimum Significant Difference in Seasonal Mean Chlorophyll-*a*

Season	JMSMH	JMSOH	JMSPH	JMSTF1	JMSTF2
Spring	2.3	3.7	1.9	3.3	1.7
Summer	1.9	3.0	1.5	3.4	3.2

ATTACHMENT C
Relative Percent Difference of Chlorophyll-*a* Measurements

The relative percent difference (RPD) of chlorophyll-*a* lab splits were calculated from 1991-200 James River data obtained from the CBMP data hub. An RPD was calculated for each sampling event for which chlorophyll-*a* data were reported for both "S1/LS1" and "S1/LS2" sample types. RPD was calculated using the following equation:

$$RPD = \left|\frac{x_1 - x_2}{(x_1 + x_2)/2}\right| \times 100$$

A total of 595 data pairs were available for the calculation. The mean RPD was 35%, but this value was strongly affected by outliers. The median RPD was 16%. There was no obvious graphical trend in RPD with chlorophyll-*a* magnitude.

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